Electronic Version
Stylesheet Version v1.1.1

Description

[PROGRAMMABLE GAMMA CIRCUIT AND DISPLAY APPARATUS THEREWITH]

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of Taiwan application 92134146, filed December 04, 2003.

BACKGROUND OF INVENTION

[0002] Field of the Invention

[0003] This invention generally relates to a Gamma modifier in an imaging processing circuit, and more particularly to a digital programmable Gamma voltage modification circuit and display apparatus therewith.

[0004] Description of Related Art

[0005] An immense variety of imaging application products is available in market in current days, where Gamma circuit is commonly included in circuitry of those products. For example, in order to drive a liquid crystal of a liquid crystal display (LCD) for displaying images, a driving voltage is

applied to a liquid crystal to rotate which by an angle, this driving voltage is provided by an image signal (usually a digital signal) after conversion. However, the image signal, driving voltage amplitude, liquid crystal angle, and pixel transmittance are not linearly related to each other, therefore a Gamma circuit is necessary for voltage manipulation for image signal modification.

[0006] Referring to *FIG. 1a*, it is a block diagram illustrating a Gamma circuit embedded in a display according to conventional art. Referring to *FIG. 1b*, it is a diagram illustrating Gamma circuit *150* in *FIG. 1a*. Referring to *FIG. 1c*, it is a diagram illustrating Gamma Circuit *140* in *FIG. 1a*. Referring to *FIGs. 1a*, *1b*, and *1c*, a driving circuit *120* is packaged as an integrated circuit (IC) and processed on a glass substrate, whereas the control/modify circuit *130* is embodied on a Printed Circuit Board (PCB). Generally speaking, an image driving circuit *120* includes a Gamma circuit *140*, wherein a plurality of resistors R41~R4n are connected serially and voltage is divided thereby. The divided voltages are amplified by voltage followers OP_{41}~OP_{4n} current wise to form Gamma voltages G_1~G_n. However, the Gamma circuit *140* is included in the driving circuit *120*, thus voltage dividers R41~R4n ratio is fixed in resis-

tance after wafer is processed. In addition to default Gamma voltages G_1~G_n, extra pins for external Gamma voltages M_1~M_n are reserved on the package of driving circuit *120* for higher flexibility.

[0007] In conventional art, if the default values G_1~G_n are to be changed in the driving circuit *120*, another Gamma circuit *150* is added to the control/modify circuit *130* for providing voltage values M_1~M_n. It was commonly done with serially connected resistors R_{51}~R_{5n} in the Gamma circuit *150* in conventional art, where voltage is divided and processed with voltage follower OP_{51}~OP_{5n} for current amplification to form Gamma voltages M_1~M_n. In the figure, each of the voltage dividers are constructed with two resistors, for example, the resistor R_{51} is comprised of resistors R_{51a} and R_{51b} connected in series. The reason why dispatching the resistors as mentioned above is because practically not all proper values of resistors are available; in order to avoid changing resistors yet retaining original divided voltage ratio, it is set up as described.

[0008] In conventional art, Gamma voltages are generated externally in replace of the embedded Gamma circuit of driving IC, thus circuit functionality is repeated and power consumption is burdened. Also, external Gamma circuit re-

quires a plurality of additional Gamma resistors and operational amplifiers, thus parts cost increases as well as area of PCB. Another Gamma circuit is provided for possible Gamma voltage modification in conventional art, yet it is not eligible to modify after manufactured. Besides, before manufactured when one of the M_1~M_n provided by Gamma circuit *150* is to be changed, all of the dividing resistors R_{51}~R_{5n} are required to be modified in the Gamma circuit *150*, which is very inconvenient and time consuming for circuit designers.

SUMMARY OF INVENTION

[0009] The present invention provides a programmable Gamma circuit. The Gamma circuit comprises a controller and a plurality of Gamma units. The controller receives external control signals, and outputs a plurality of Gamma setup signals according to the control signals. Each Gamma setup signal is comprised of a plurality of bit signals in digital form. According to one preferred embodiment of the present invention, the control signals are transmitted via I^2C or 3-wire interface bus, so that number of pins of driving IC is reduced. Each Gamma unit receives a Gamma setup signal, and outputs a corresponding Gamma voltage signal upon the Gamma setup signal that is received.

[0010] According to one preferred embodiment of the present invention, the foregoing Gamma unit includes an operational amplifier and a plurality of Gamma resistors. Each of the Gamma resistors has a first terminal and a second terminal, and the first terminal of each of the Gamma resistors receives one of the bit signals from each of the Gamma setup signals. The second terminal of each of the Gamma resistors is coupled together for outputting a summed up current from the gamma resistors as a Gamma current. The amplifying unit is for receiving the Gamma current, and transferring which to a corresponding Gamma voltage signal for output. The foregoing amplifying unit, including a feedback resistor and an operational amplifier, is exemplary in a preferred embodiment of the present invention. The feedback resistor has a third terminal and a fourth terminal, and the operational amplifier has a first input terminal, a second input terminal and an output terminal. The first input terminal of the operational amplifier is coupled to a voltage level, and the second input terminal is coupled to the third terminal of the feedback resistor and receives the Gamma current. The output terminal of operational amplifieris coupled to the fourth terminal of the feedback resistor for outputting

Gamma voltage signal. Wherein the voltage level is ground voltage level or any direct voltage level.

[0011] The present invention is applied to display apparatus, or a liquid crystal display for further description, yet not limiting the scope of the present invention thereby. Display apparatus is merely one of the applications for the present invention.

[0012] The present invention provides another programmable Gamma circuit, including an amplifying unit and a plurality of Gamma resistors. A plurality of external Gamma setup signals is provided in digital form. Each of the Gamma resistors has a first terminal and a second terminal, where the first terminal receives one of the Gamma setup signals, and the second terminal is coupled together and outputs a summed Gamma current from each of the Gamma resistors. The amplifying unit is for receiving the Gamma current, and transfers which to a corresponding Gamma voltage signal.

[0013] The amplifying unit provides a simple circuit in one preferred embodiment, including a feedback resistor and an operational amplifier. Wherein the feedback resistor has a third terminal and a fourth terminal, whereas the operational amplifier has a first input terminal, a second input

terminal and an output terminal. The first input terminal of the operational amplifier is coupled to a voltage level; the second input terminal is coupled to the third terminal of the feedback resistor and receives the Gamma current. The output of the operational amplifier is coupled to the fourth terminal of the feedback resistor and outputs the Gamma voltage signal. Wherein the voltage level is ground voltage level or any other direct voltage level.

[0014] The present invention adopts I^2C or 3-wire transmission interface bus for control signal transmission, thus number of IC pins is significantly reduced comparing to conventional IC. On the other hand, programmable Gamma voltage is also provided, thus external Gamma circuit is eliminated, so that chip area is saved, power consumption is reduced, and cost is lowered. Most significantly, the present invention provides possible modification of Gamma voltages upon user's request at any time.

[0015] The present invention provides a display apparatus, including a display panel, a control/modify circuit and a driving circuit. The control/modify circuit outputs a plurality of Gamma setup signals in digital form including a plurality of bit signals. The driving circuit is coupled to the control/modify circuit and the display panel, wherein the

driving circuit includes a programmable Gamma circuit. The programmable Gamma circuit receives a plurality of Gamma setup signals, and outputs corresponding Gamma voltage signals.

[0016] According to the preferred embodiment of the present invention, the programmable Gamma circuit includes a plurality of Gamma units, each Gamma unit receives one of the Gamma setup signals, and outputs one of the corresponding Gamma voltage signals according to the Gamma setup signals that is received. Notice that the display panel is liquid crystal display, for example.

[0017] The above is a brief description of some deficiencies in the prior art and advantages of the present invention. Other features, advantages and embodiments of the invention will be apparent to those skilled in the art from the following description, accompanying drawings and appended claims.

Brief Description of Drawings

[0018] *FIG. 1a* is a diagram illustrating a Gamma circuit for a display apparatus according to a conventional art.

[0019] *FIG. 1b* is a circuit diagram illustrating the Gamma circuit *150* in *FIG. 1a* according to conventional art.

[0020] *FIG. 1c* is a circuit diagram illustrating the Gamma circuit

140 in *FIG. 1a* according to conventional art.

[0021] *FIG. 2* is a block diagram illustrating a programmable Gamma circuit according to one preferred embodiment of the present invention.

[0022] *FIG. 3* is a block diagram illustrating the programmable Gamma circuit *240* in *FIG. 2* according to one preferred embodiment of the present invention.

[0023] *FIG. 4* is a circuit diagram illustrating the Gamma unit *244* according to one preferred embodiment of the present invention.

DETAILED DESCRIPTION

[0024] Referring to *FIG. 2*, it is a block diagram illustrating a programmable Gamma circuit according to one preferred embodiment of the present invention. *FIG. 2* is a block diagram illustrating the programmable Gamma circuit *240* in *FIG. 2*. *FIG. 4* is a block diagram illustrating the programmable Gamma unit *244* in *FIG. 3* according to one preferred embodiment of the present invention. Referring to *FIGs. 2*, *3* and *4*. For further description of the present invention, liquid crystal display is exemplary hereinafter. The liquid crystal display has a display panel *210*, wherein images are comprised of a plurality of pixels of the display panel *210*. The pixels perform along with transmit-

tance variation upon liquid crystal rotation, which is controlled by different driving voltage. The driving circuit *220* for providing driving voltage is integrated to an IC and is disposed on a same glass substrate with the display panel *210*. On the other hand, the PCB technology applies to the control/modify circuit *230* for providing control and clock signals for the driving circuit *220*. The pre-embedded Gamma circuit of the driving circuit *220* is entirely integrated to the programmable Gamma circuit *240* accordingly.

[0025] In the present invention, such as I^2C or 3-wire interface buses are applied to the programmable Gamma circuit *240*. Therefore number of IC pins is significantly reduced. In one preferred embodiment of the present invention, I^2C interface bus is exemplary. I^2C interface bus is a two-wire transmission interface, having a serial data line SDAT and serial clocking line SCLK. Control signals are transmitted serially externally via the serial data line SDAT to the controller *242*. The controller *242* captures the control signal via the serial data SDAT upon the serial clock signal SCLK triggers. The controller *242* sets off and keeps a plurality of Gamma setup signals $V_1 \sim V_n$ according to the control signals, and each of the Gamma setup signals are com-

prised of a plurality of bit signals in digital form. For example, the Gamma setup signal V_n is an 8-bit signal, represented by bit signal V_{n1} to bit signal V_{n8} in this preferred embodiment of the present invention.

[0026] Each of the Gamma units *244* receives the corresponding Gamma setup signal, and determines a Gamma voltage for outputting according to the Gamma setup signal that is received. The n^{th} Gamma unit is described as an example herein, whereas other Gamma units are not repeated hereafter. The Gamma unit *244* receives the Gamma setup signal V_n, wherein the Gamma setup signal V_n includes bit signal V_{n1} to bit signal V_{n8}. In the preferred embodiment of the present invention, the Gamma unit *244* includes eight Gamma resistors, which possess resistance of R, 2R, 4R, 8R, 16R, 32R, 64R, and 128R respectively, for example, where R is a positive number. In favor of description convenience, the resistors are named after their resistance hereinafter. Referring to *FIG. 2*, the Gamma resistor R receives the Gamma setup signal V_{n1}, the Gamma resistor 2R receives the Gamma setup signal V_{n2}, and likewise for the rest of Gamma setup signals. Each of the Gamma resistors receives bit signals for generating current, and summing up each current from the Gamma resistors as

the Gamma current *247*. The amplifying unit transfers the Gamma signal *247* to a Gamma signal G_n for outputting accordingly.

[0027] A simple circuit of amplifying unit *250* is embodied in one preferred embodiment of the present invention, including a feedback resistor *252* and an operational amplifier *254*. Wherein one input terminal of the operational amplifier *254* is coupled to the voltage level *251* and the other input terminal is coupled to the feedback resistor for receiving the Gamma current *247*. The output terminal of the operational amplifier *254* is coupled to the feedback resistor *252* and outputs the Gamma voltage signal G_n. The voltage level *251* is ground voltage level, for example, or any other direct voltage level. The resistance of the feedback resistor *252* is R ohms, for example, where R is a positive number.

[0028] When the Gamma setup signal V_n is 00000001, for example, the bit signal V_{n1} is at high voltage level (e.g. v volts), and the rest bit signals V_{n2}~V_{n8} are at low voltage level (e.g. 0 volt). The gamma current *247* is thus v/R amperes, and the Gamma voltage signal G_n is (v/R)R=v. If the Gamma setup signal V_n is 00000010, for example, the bit signal V_{n2} is at high voltage level, and the rest of the bit

signals V_{n1}, V_{n3}~V_{n8} are at low voltage levels. Where the Gamma current *247* is v/2R amperes, and the Gamma voltage signal G_n is (v/2R)R=v/2. Also when the Gamma setup signal V_n is 00000011, for example, that is the bit signals V_{n1} and V_{n2} are at high voltage level, and the rest of bit signals V_{n3}~V_{n8} are at low voltage level. The Gamma current *247* is then (v/R)+(v/2R)=3v/2R amperes, and the Gamma voltage signal G_n is thus (3v/2f)R=3v/2. Therefore by controlling signals (SCLK+SDAT) manage to setup each of the Gamma units *244* for outputting expected Gamma signals G_1~G_n.

[0029] It is noted that for the skill in the art, number and resistance of the resistors *246* can be modified upon request, and the combinations of the bit signals of the Gamma setup signals are not limited. Variations of aforementioned are also within the scope of the present invention.

[0030] Referring to *FIGs. 2*, *3*, and *4* for another preferred embodiment of the present invention. This present preferred embodiment is similar to the previous preferred embodiment, whereas the controller *242* of the programmable Gamma circuit *240* is omitted, yet programmable setup signals V_1~V_n in digital form are provided externally.

[0031] Referring to *FIG. 2* again for another preferred embodi-

ment of the present invention. The output signals of the control/modify circuit *230* in this preferred embodiment includes a plurality sets of Gamma setup signals V_1~V_n, and are transmitted to the driving circuit *220*, for example. The Gamma setup signals are in digital form and each of the Gamma setup signals includes a plurality of bit signals. The driving circuit *220* has programmable Gamma circuit, which serves to receive each set of the programmable setup signals, and output corresponding Gamma voltage signals according to the Gamma setup signals. In this preferred embodiment, the programmable Gamma circuit includes a plurality of Gamma units, each of the Gamma unit receives one of the Gamma setup signals, and outputs one of the corresponding Gamma setup signals upon the Gamma setup signal that is received. The Gamma unit is embodied according to *FIG. 4*, for example, which is similar to the previous preferred embodiment, thus is not repeated herein.

[0032] Moreover, when the Gamma voltages G_1~G_n are modified according to the characteristics of the display, designers manage to merely modify the control signals of the control/modify circuit *230* to obtain different values of the Gamma setup signals V_1~V_n for obtaining the Gamma

voltages G_1~G_n as expected. Yet comparing to conventional art, the present invention is superior whereas all resistors needed to be modified for varying Gamma voltages in prior art.

[0033] The above description provides a full and complete description of the preferred embodiments of the present invention. Various modifications, alternate construction, and equivalent may be made by those skilled in the art without changing the scope or spirit of the invention. Accordingly, the above description and illustrations should not be construed as limiting the scope of the invention which is defined by the following claims.